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CENOSITE FROM NORTH BURGESS TOWNSHIP, LANARK COUNTY, ONTARIO

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INTRODUCTORY

Some years ago Dr. W. F. Ferrier and Mr. W. L. McLaren noted the occurrence of minute pink or pale rose colored crystals on some specimens of calcite and quartz that they collected on lot 8, con. V, North Burgess township, Lanark county, Ontario. Ferrier recognized that these crystals did not resemble any known species, and he therefore concluded that they must either be a new mineral, or else an unusual variety of a very rare one. At that time, a specimen carrying a few of the pink crystals was sent to one of the writers for examination, and the results of this appeared to confirm the view that the species was new, since search of the literature revealed no other mineral having the same specific gravity, crystal angles, and refractive indices. At a later date, Ferrier and McLaren furnished the writers with a suite of specimens, and it has been possible to make a more complete examination of the material, including a detailed chemical analysis.

As will appear, the mineral has essentially the same composition as cenosite, and like the latter it is orthorhombic. Here, however, any very close resemblance between the two ceases. The crystal constants of the Ontario material are quite markedly different from those recorded by Sjögren for cenosite from Nordmark, and the same is true of the refractive indices, which were determined for the Nordmark cenosite by E. S. Larsen. The Ontario mineral has a specific gravity of 3.612, as compared with 3.413 for cenosite from Hitterö and 3.38 for that from Nordmark, and its color ranges from very pale to deep pink, whereas cenosite from the two previously recorded localities is described as yellow-brown to dark chestnut-brown.

Until the chemical analysis had been completed, there was, therefore, little to indicate that the mineral might be identical with, or even closely related to, cenosite. On learning that it was probably a new species, Mr. W. L. McLaren, of Forest Lodge, Perth, Ontario, who has contributed so largely to the knowledge and preservation of the minerals of the district in which he lives, devoted a great deal of his time during three seasons to collecting all the specimens he could find of the mineral.

There are three published analyses of cenosite—two by A. E. Nordenskiöld of the original material from Hitterö, and one by R. Mauzelius on 0.0666 grams of material from the Nordmark locality. The results of these analyses, and also of that of the North Burgess mineral, are reproduced below. As will be noted, these analyses differ from one another in several important respects, which are discussed in the section dealing with the chemical composition; but in their main essentials there is a fairly close correspondence, and the North Burgess analysis agrees as closely with the analyses of the two accepted occurrences of cenosite as do these with one another. Under the circumstances, therefore, it seems best to regard the North Burgess mineral also as cenosite, and not as a new species closely related to cenosite. The differences observed in its crystallographic, optical, and other characters, as compared with those previously recorded for cenosite, must be ascribed either to variations in the compositon, which is both complex and unusual, or to the fact that the material available from the Hitterö and Nordmark localities was both poor and scanty, as witness the very small amount used by Mauzelius in his analysis.

HISTORICAL

Cenosite, or more properly kainosite, was first described by A. E. Nordenskiöld in 1886[1] from Igeltjern, on the island of Hitterö, Norway, and was so named owing to its peculiar composition (καιγός, unusual). The mineral was obtained only in a single specimen as a fragment of a six-sided prismatic crystal, which appeared to be either orthorhombic or monoclinic, and was described as having a distinct cleavage in one direction, and indistinct cleavage along two other planes inclined at 90° or thereabouts. The material was yellowish-brown and semi-transparent, with a somewhat greasy lustre, resembling in this respect apatite and nephelite. H = 5.5. Sp. Gr. = 3.413. Nordenskiöld gave the results of two analyses of the cenosite (see below), and from these he deduced the formula: $4SiO_2+CO_2+(Yt_2O_3,Er_2O_3)+2CaO+2H_2O$.

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[1] Kainosit, ein neues Mineral von Hitterö in Norwegen: *Geol. Fören. Förhandl.*, **1886**, 8, pp. 143–146.

He called attention to a possible relationship in chemical constitution between cenosite and cancrinite. The mineral is soluble in acids, slowly in the cold and readily when heated, with evolution of carbon dioxide. It gives off water at a low red heat, and carbon dioxide at a higher temperature, and fuses with difficulty to a white enamel.

The only other recorded occurrence of cenosite is at the Ko mines, Nordmark, Sweden, and was described by H. J. Sjögren in 1897.[2] Here the mineral occurs in short prismatic crystals (orthorhombic) which have a yellow-brown to dark chestnut-brown color and a greasy lustre. Cleavage was not observed. $H=5\text{-}6$. Sp. Gr. $=3.38$. Common forms: $m\{110\}$, $c\{001\}$, $d\{011\}$, with subordinate $b\{010\}$, $e\{021\}$, $f\{023\}$, $g\{201\}$, and $h\{230\}$. Sjögren states that the basal plane is often rounded and the brachydomes corroded, so that the crystals do not lend themselves to accurate measurement. He gives the angles $(110):(\bar{1}10)=92°\ 50'$ and $(011):(010)=41°\ 33'$, and the axial ratio $a:b:c=0.9517:1:0.8832$; and he calls attention to the fact that this axial ratio is near that of cerite, for which $a:b:c=0.9988:1:0.8127$.

It has been pointed out (see *Dana*, Appendix I, p. 15) that the value 41° 33′, given in Sjögren's original paper as the angle (011):(010), is not in agreement with his calculated axial ratio, and assuming the latter to be correct the angle (011):(010) is 48° 33′.

Sjögren's paper did not contain any account of the optical characters of the mineral, but in a footnote he stated that these were to be dealt with in a subsequent paper, which was to contain also further crystallographic data and figures of the crystals. This supplementary paper, apparently, was never published. The paper cited, however, gives the results of an analysis by R. Mauzelius. This is reproduced below.

The Nordmark cenosite occurs in druses, which have apparently originated through the solution of calcite, in the fine grained magnetite ore of the Ko mine. The associated minerals are diopside, magnetite, clinochlore, and apatite, which have been formed in the order named. The cenosite crystallized last of all, as isolated crystals a few millimeters in size.

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[2] Kainosit von der Kogrube im Nordmarkgebiet: *Geol. Fören. Förhandl.*, **1897**, 19, pp. 54–60.

The only other original reference to cenosite that can be found is in a paper by E. S. Larsen[3], who gives the following optical characters for the Nordmark mineral: Optically–, $2V$ = medium large. Brownish and clouded in section and non-pleochroic.

$$\alpha = 1.667 \pm 0.003,\ \beta = 1.681 \pm 0.003,\ \gamma = 1.683 \pm 0.003.$$

MODE OF OCCURRENCE OF THE NORTH BURGESS CENOSITE

The following particulars are from notes kindly communicated to the writers by Dr. Ferrier, Mr. McLaren, and Dr. Chas. Palache.

The specimens came from an old pit about 50 feet deep, now filled with water, which was originally opened for apatite on a vein running north and south. It was also worked for mica some years prior to 1907 and again in that year.

The indications are that the material in which the cenosite occurs was taken out during the last days of the work done in 1907, which consisted of drifting along the vein at a depth of 25 feet from the surface.

In the dump there are large masses of brecciated material made up of phlogopite, apatite, and calcite which are often coated with a later layer of calcite, and it appears as if the cenosite and its closely associated minerals have been formed in solution cavities in this calcite.

The specimens showing cenosite have a matrix of coarsely granular limestone containing apatite grains, plates of phlogopite, and a few grains of sphalerite. Solution cavities in the limestone are lined with crystals of quartz or of calcite. In some cavities, planted on both these minerals, are crystals of cenosite. Chalcopyrite, in well formed but deeply striated crystals, is sparsely present. The latest mineral to form is celestite, in platy aggregates which sometimes cover all the other minerals on the cavity walls.

On one specimen, tiny rosettes of silvery needles are implanted on quartz and calcite. Optical tests indicated that these are a soda pyroxene near aegirite. The needles are thin blades.

The order of deposition may be shown approximately by the following diagram:

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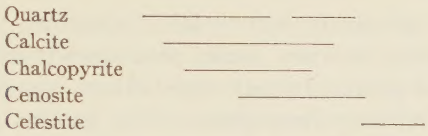
[3] The Microscopic Determination of the Non-opaque Minerals: *U. S. G. S., Bull.* **679**, 1921, p. 54.



Calcite.—The crystals are combinations of the scalenohedron $v(21\bar{3}1)$ with $r\ (10\bar{1}1)$ and $f\ (02\bar{2}1)$. The faces of v are bright but uneven; r is smooth and dull; f is bright. The scalenohedron is dominant in most crystals, and on those in some of the cavities the unit rhombohedron has been overgrown at a late stage by rounded scalenohedral faces. On crystals in other cavities, the scalenohedral faces are reduced to mere lines on the edges of the rhombohedron. The color of the calcite is pale buff to faintly pink.

Quartz.—The crystals are of the common habit, with prism $m\ (10\bar{1}0)$ dominant, $r\ (10\bar{1}1)$ and $z\ (0\bar{1}11)$ generally equally developed. A marked etching of the prism faces is noteworthy, in its early stages developing narrow straight furrows but finally producing a network of grooves which destroys the lustre of the faces. A rounding of three alternate edges of the prism was also noted. The rhombohedra r and z remain quite unetched.

Clear transparent crystals, some up to 2 inches in length and doubly terminated, have been found at the locality.

Apatite.—Besides the massive variety, small doubly terminated translucent crystals of a bright green color occur imbedded in a white calcite.

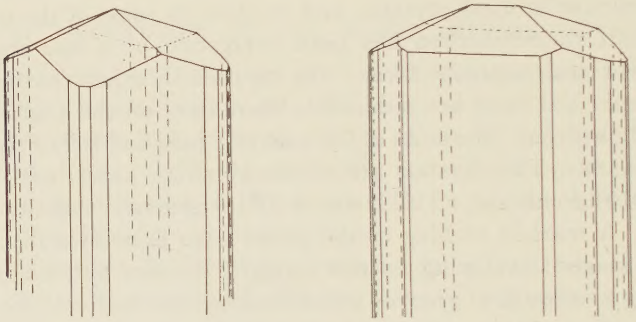
Pyrite.—One or two sharp-angled, brilliant, elongated octahedra up to three-quarters of an inch in length, resembling closely the well-known crystals from French Creek, Penna., were found.

Sphalerite.—This mineral occurs rarely at the locality in very small well formed isolated tetrahedral crystals, which are sometimes twinned.

Crystallography

The best crystallographic material consists of minute prismatic crystals, 0.5 to 1.0 mm. in diameter, which occur either as isolated crystals, which may be doubly terminated, or in more or less solid crusts from which the free ends of the prisms, singly or in interfering groups, project. Less commonly the crystals are larger than this, and on some of the specimens there are composite crystals in nearly parallel intergrowth which measure half an inch across.

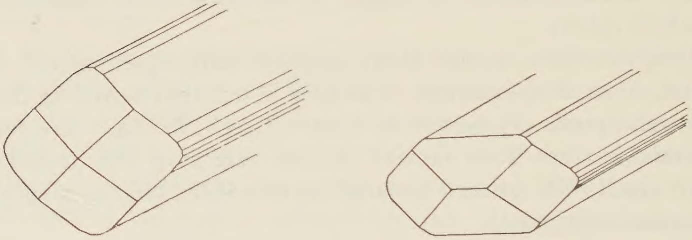
The smaller crystals are perfectly transparent and nearly colorless, but invariably with a faint pink tint. With increase in size this color becomes more pronounced until in the larger crystals and more coarsely crystallized material the color is rose-red to a fairly deep pink. The greater depth of color is accompanied by a loss in transparence, the larger crystals being clouded and some of them barely translucent.



PRISMATIC ORIENTATION

$a:b:c=0.8759:1:0.4638$

Forms: (101), (011), (100), (320), (110), (340), (120), (010).



SJÖGREN'S ORIENTATION

$a:b:c=0.9517:1:0.8832$

Forms: (001), (023), (011), (043), (021), (010), (201), (210).

In the orientation adopted here, the direction of elongation of the crystals is taken as the prism zone, although, as noted below it is believed that this is not the same as Sjögren's orientation. Regarded in this way, the typical crystals are orthorhombic prisms terminated at either end by four faces of the macro and brachy domes or prisms. The prism zone usually includes, in addition to the dominant unit prism, narrow faces of several other prisms and also of the macro and brachy pinacoids; and the large, deeply colored crystals, while still prismatic in habit, are commonly tabular owing to the relatively large development of the macro pinacoid *a* (100). The accompanying figures illustrate these two habits. The basal pinacoid, recorded by Sjögren as a dominant form on the Nordmark cenosite, was not observed on any of the crystals measured or examined.

Although the small, transparent crystals appear at first sight to be almost ideal for measurement, it was found that as often as not the faces yield diffuse or multiple images. In the prism zone the multiple images are due to the presence of extremely narrow faces of a series of nearly coincident prisms, as a result of which there is a tendency to curvature. In some of the crystals measured also, the dome faces, and especially the brachy dome faces, were found to be composite, each consisting of two faces meeting in an edge in the direction of the vertical axis and inclined to one another at a salient angle ranging up to about 5 degrees. No evidence of twinning was observed, however, either on the goniometer or in the course of the optical examination of the crystals.

In all, fifteen crystals were measured. The results tabulated below are based on the most reliable and consistent of the readings obtained. Owing to the uncertainty whether the orientation adopted here is the same as that of Sjögren, it has been thought advisable to derive the crystal constants independently and for this purpose the dominant prism is taken as the unit prism (110), and the only two domes observed on the crystals are taken as the unit domes (101) and (011).

System: Orthorhombic (Normal Class)

$a:b:c=0.8759:1:0.4638$; $p_0=0.5295$, $q_0=4638$. Forms observed: (100), (010), (120), (340), (450), (110), (320), (101), (011).

In addition to the above, one or more faces of the following prisms are present on some of the crystals measured: (490), (590), (230), (670), (780), (890), (11.12.0), (650), (430).

Table of Calculated and Observed Angles

Symbol		Calculated		Measured		No.	Limits, ϕ or ρ
Mlr	Gdt.	ϕ	ρ	ϕ	ρ		
100	$\infty 0$	—	—	—	—		—
010	0∞	—	—	—	—		—
120	$\infty 2$	29°43′	90°00′	29°49′	90°00′	16	28°15′–31°28′
340	$\infty {}^4/{}^3$	40 34	90 00	40 37	90 00	6	39 44 –41 43
450	$\infty {}^5/{}^4$	42 24	90 00	42 42	90 00	6	42 05 –43 09
110	∞	48 47	90 00	48 47	90 00	50	47 47 –49 37
320	${}^3/{}^2 \infty$	59 43	90 00	59 42	90 00	5	58 40 –60 36
101	10	90 00	27 54	90 00	27 54	6	27 47 –27 58
011	01	00 00	24 53	00 00	24 55	7	24 09 –25 30
490	$\infty {}^9/{}^4$	26 54	90 00	27 11	90 00	9	26 21 –27 46
590	$\infty {}^9/{}^5$	32 23	90 00	32 30	90 00	3	32 16 –32 43
230	$\infty {}^3/{}^2$	37 16½	90 00	37 14	90 00	1	37 14
670	$\infty {}^7/{}^6$	44 23	90 00	44 13	90 00	4	43 54 –44 37
780	$\infty {}^8/{}^7$	44 58	90 00	44 52	90 00	2	44 51 –44 53
890	$\infty {}^9/{}^8$	45 25	90 00	45 35	90 00	3	45 22 –45 59
11.12.0	$\infty {}^{12}/{}^{11}$	46 18	90 00	46 36	90 00	4	46 19 –46 58
650	${}^6/{}^5 \infty$	53 52	90 00	54 00	90 00	2	53 38 –54 21
430	${}^4/{}^3 \infty$	56 42	90 00	56 48	90 00	2	56 46 –56 50

Comparison with Sjögren's Data:

As stated above, Sjögren recorded the following forms on cenosite from Nordmark: *b*(010), *c*(001), *m*(110), *h*(230), *g*(201), *f*(023), *d*(011), and *e*(021). He gave the angle $(110):(\bar{1}10) = 92° 50'$, and $(011):(010) = 41° 33'$ (the latter presumably a misprint for 48° 33′), and also the axial ratio $a:b:c = 0.9517:1:0.8832$.

On the assumption that the orientation adopted for the North Burgess cenosite is the same as that of Sjögren, there is a rather remarkable difference in the forms exhibited by the crystals from the two localities. Thus, the basal pinacoid, a dominant form on the Nordmark crystals, is apparently never present on those from North Burgess. On the other hand, the case is just the reverse with the macro pinacoid, *a*(100), which usually appears, and is sometimes very largely developed, on the North Burgess crystals, but is not recorded on those from Nordmark. Lastly, there are three brachy domes on the Nordmark crystals, whereas on those here described there is only one; and the latter exhibit a series of forms in the prism zone, as compared with only two prisms on Sjögren's crystals.

These divergences would largely disappear by a transposition of the *a* and *c* crystal axes; and if at the same time the unit length of the former *c* axis for the North Burgess crystals is doubled, the crystal constants become more nearly comparable, as follows:

	$a:b:c$	p_0	q_0
Nordmark	0.9517:1:0.8832	0.9280	0.8832
North Burgess, with *c* doubled and *a* and *c* transposed	0.9276:1:0.8759	0.9443	0.8759

Unfortunately, the writers have not a crystal of the Nordmark cenosite at their disposal to test this point, which might be done by measurement of one or two of the crystal angles combined with an observation of the optical characters. Should this be the correct explanation of the apparent differences in crystallographic characters of the material from the two localities, the forms present on the North Burgess cenosite, using Sjögren's orientation, would be as shown in column 4 in the accompanying table. The nine prismatic forms which were observed only as occasional very narrow faces on the North Burgess crystals are not included in the table. None of these are recorded on the Nordmark cenosite. They would become brachy prisms or domes, and their symbols would remain the same with transposition of the *a* and *c* intercepts [4]

[4] Since the above was written, Professor C. Palache has very kindly furnished the writers with a crystal of the Nordmark cenosite, and it has been possible to compare the orientation adopted here for the North Burgess crystals with that of Sjögren. On the basis of the latter, the crystal is a simple orthorhombic prism terminated by the basal plane, with minute faces of the brachy prism or dome (011). The prism angle, from two fair faces, was measured as 93° 20′ ($\phi = 46° 40'$), and the angle between the basal plane and the dome as about 43° 04′, both faces yielding very faint images. On this particular crystal, therefore, the prism and dome angles are practically identical ($110:1\bar{1}0 = 86° 40'$ and $011:0\bar{1}1 = 86° 08'$), and transposition of the *a* and *c* crystal axes would not materially affect the values of the crystal constants. It was not found possible to make an accurate determination of the refractive indices, but results obtained by the immersion method showed that, using Sjögren's orientation, crystal axis $a = \alpha$, $b = \beta$, and $c = \gamma$. In the North Burgess crystals, on the other hand, the acute bisectrix, α, is in the direction of elongation of the crystals, here taken as the crystal axis *c*, and $a = \gamma$, $b = \beta$, and $c = \alpha$. It is definitely established, therefore, that to correspond with Sjögren's orientation, the North Burgess crystals must be regarded as elongated along the *a* crystal axis and not as prismatic in the ordinary sense of the term. The crystals are far superior, however, to those hitherto known from Hitterö or Nordmark, and for this reason it may be deemed preferable to adopt for the mineral the new prismatic orientation and the crystal constants as given in the body of this paper.

COMPARATIVE TABLE OF FORMS

Letter (Sjögren)	For axial ratio $a:b:c$ .8759:1:.4638	For axial ratio $a:b:c$ .8759:1:.9276	For axial ratio $a:b:c$ .9276:1:.8759	Calculated Angles	
				North Burgess	Nordmark‡
c	(100)	(100)	(001)*	—	—
b	(010)	(010)	(010)*	—	—
e	(120)	(120)	(021)*	$\rho=60^\circ17'$	$\rho=60^\circ29'$
	(340)	(340)	(043)		
	(450)	(450)	(054)		
d	(110)	(110)	(011)*	$\rho=41\ 13$	$\rho=41\ 27$
f	(320)	(320)	(023)*	$\rho=30\ 17$	$\rho=30\ 29$
g	(101)	(102)	(201)*	$\rho=62\ 06$	$\rho=61\ 42$
	(011)	(012)	(210)	$\phi=65\ 07$	$\phi=64\ 33$
m			(110)*†	$\phi=47\ 09$	$\phi=46\ 25$
h			(230)*†		$\phi=35\ 01$

* Forms recorded by Sjögren on crystals from Nordmark.
† These forms were not observed on the North Burgess crystals.
‡ Calculated from Sjögren's axial ratio, $a:b:c=0.9517:1:0.8832$.

OPTICAL CHARACTERS

The refractive indices were determined by the total reflection method, the crystal being suspended and immersed in a liquid of index 1.7335. For this purpose the larger deep-pink crystals were used, total reflection being obtained from a polished face of the prominent macro pinacoid, *a* (100), and also from a polished surface cut at right angles to the prism zone and representing the basal plane. (The 'prismatic' orientation of the crystals is here referred to.) The results of a series of fairly consistent determinations gave refractive indices as follows, for sodium light: $\alpha=1.664$, $\beta=1.689$, $\gamma=1.691$. (All ± 0.001).

Crystal axis $a=\gamma$, $b=\beta$, $c=\alpha$. If the axes *a* and *c* are transposed, this becomes $a=\alpha$, $b=\beta$, $c=\gamma$.

The mineral is optically negative, with strong dispersion, $\rho<v$.

The optic axial angle for sodium light was measured in air and also in the liquid of refractive index 1.7335, with results as follows:

$$2E=70^\circ\ 32', \text{ giving } 2V=39^\circ\ 59'$$
$$2H=38^\circ\ 38', \quad '' \quad \bar{2}V=39^\circ\ 42'$$

As calculated from the refractive indices, $2V=31°\ 20'$. This is in as close agreement with the other calculated values as might be expected. An error of 0.001 in the determination of either of the indices β and γ, making them respectively 1.688 and 1.692, or a much smaller error in both β and γ, but in oppostie directions, would be sufficient to account for the difference. Thus, the indices $\alpha=1.664$, $\beta=1.6884$, $\gamma=1.6916$ would give $2V=39°\ 20'$. It is probable, therefore, that the true internal optic axial angle for sodium light is near 39° 45′.

The only published data on the optical characters of cenosite are those of E. S. Larsen,[5] who gives the refractive indices for the Nordmark material as: $\alpha=1.667$, $\beta=1.681$, $\gamma=1.683$, all ± 0.003. These indices were determined by the immersion method. It is certain that, for the North Burgess cenosite, the values of both β and γ are considerably higher than those given by Larsen.

OTHER CHARACTERS

Hardness between 5 and 6. Specific Gravity, 3.612. Lustre vitreous, with tendency to pearly on some faces. Cleavage not observed. Fracture uneven.

Soluble in hydrochloric acid with evolution of carbon dioxide, and with separation of gelatinous silica on evaporation. A fragment of standard size heated before the blowpipe expands or exfoliates somewhat and fuses on corners or small projections to a whitish enamel. Flame coloration, yellowish-red (calcium).

CHEMICAL COMPOSITION[6]

The material available for analysis consisted of a little less than two grams of clean transparent to translucent crystals and crystal fragments which had been very carefully selected by Graham under the microscope. This was further checked by Ellsworth under the binocular microscope equipped with a Silverman illuminator and not the slightest trace of foreign matter could be seen. Thus it may be stated with confidence that only crystal material of apparently unimpeachable purity was comprised in the lot analyzed.

Two specific gravity determinations were made on the whole 2 gram lot, using a silica pycnometer. One determination at 20.60°

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[5] The Microscopic Determination of Non-opaque Minerals: *U. S. Geol. Surv., Bull.* **679**, 1921, p. 54.

[6] Published by permission of the Director, Geological Survey of Canada.

C. gave the result 3.612, the other at 23. 32° yielded the value 3.610.

After taking the specific gravity, the mineral was allowed to dry in the air at ordinary temperature and was then crushed and ground for analysis. One gram of the air-dry mineral was taken for the main analysis. This was heated first at 110° C. and later as high as 130°. The total loss after 4 hours heating from 110° to 130° was 0.04 per cent.

The mineral, in a platinum crucible, was then ignited to drive off CO_2 and water. After ignition at a full red heat for about two minutes the loss was 0.31 per cent. Evidently the water is firmly held and must be considered as hydroxyl of constitution. Ignition was continued, at first with a large Meker burner and finally by blasting. The following table shows the course of the loss and the long time required to drive off the last traces of CO_2.

Time	Heat	Total Loss in Percent from Air Dry Condition, Including Crucible Loss
4 hrs.	110°–130°	0.04
2 mins.	Meker	0.31
30 "	"	8.43
30 "	"	8.58
15 "	"	8.64
15 "	Blast	9.06
15 "	"	9.11
15 "	"	9.15
15 "	"	9.18
15 "	"	9.24
15 "	"	9.24

After the crucible loss is deducted from the above values the net total loss is 9.16 per cent.

There was no evidence of the loss of any volatile oxides, as the under side of the crucible lid remained absolutely clean throughout the ignition. This ignited material was used for the main analysis. The ignited mineral did not show any indication of fusion and it appeared to be attacked by hydrochloric acid perhaps even more readily than the original mineral.

Water was determined directly on a separate portion of about a half gram.

The difference between loss by ignition and total water plus SO_3 is considered to represent the carbon dioxide present. A qualitative test on a small quantity of the mineral in which the gas was passed through barium hydroxide solution proved that CO_2 is present in important quantity, and as there are no oxides present which might gain weight on ignition, except a very little iron and cerium, the determination of CO_2 by difference should be reasonably exact.

The possible relationship of the mineral to cancrinite and microsommite suggested the necessity of tests for SO_3 and Cl. A little SO_3 was found but no chlorine. Fluorine, also, was not detected, and electroscopic and chemical tests for thorium gave negative results. The cerium group was separated from the neutral

ANALYSES OF CENOSITE

	NORTH BURGESS ONT. (Ellsworth)	HITTERÖ (Nordenskiöld)		NORDMARK (Mauzelius)
		A	B	
SiO_2	34.66	34.05	35.21	31.7
$(Ce, La, Di)_2O_3$	3.22[1]	trace	trace	—
$(Yt, Er)_2O_3$	35.46[2]	38.00	37.34	35.9
CaO	16.72	16.10	15.80	16.5
SrO	0.31[3]			
Al_2O_3, Fe_2O_3, BeO, etc.	0.22[4]	0.29†	0.22†	2.9‡
MnO	0.02	—	—	—
Na_2O	0.27	0.38	0.43	3.6
K_2O	trace	—	—	
MgO	0.19	0.04	0.03	1.4
CO_2	6.58	5.54	6.25	[5.1]
SO_3	0.04[5]	—	—	—
H_2O	2.54	[5.60]	4.92	2.9
H_2O 110°–130°	(0.04)			
Total	100.23	100.00	100.20	100.0
Sp. Gr.	3.612	3.413	3.413	3.38

† FeO. ‡ Fe_2O_3.

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[1] The oxides after heating in air were a strong brown colour indicating the presence of considerable praseodymium. After heating in hydrogen they became white.

[2] Mean equivalent atomic weight by oxide-sulfate ratio about 108.4.

[3] Barium not detected by flame test. The strontium was separated by repeated amyl alcohol treatments and appeared perfectly pure.

[4] Little iron, apparently mostly alumina. No test for beryllium.

[5] Determined on 0.2 grams.

rare-earth sulphates by two precipitations with potassium sulphate.

Special care was taken to be certain that all the calcium was separated from the rare earths, as small quantities are likely to be rather tenaciously retained by rare-earth precipitates.

The analysis yielded results as shown in the preceding table, analyses of the Hitterö and Nordmark minerals being included for comparison.

As may be seen from the following tables of molecular ratios, the North Burgess mineral comes about as close to the composition expressed by the formula $2CaO \cdot Yt_2O_3 \cdot 4SiO_2 \cdot CO_2 \cdot 2H_2O$, which was proposed by Nordenskiöld for the Hitterö mineral, as does the Hitterö cenosite itself, with the exception that the Canadian mineral has only one molecule of water.

BURGESS CENOSITE

	MOL. RATIO	
SiO_2—	34.66÷60.1 =0.5767	÷4=0.1442
$(Ce, La, Di)_2O_3$—	3.22÷330 =0.0097	÷1=0.1452
$(Yt, Er)_2O_3$—	35.46÷265 =0.1338	
Al_2O_3, etc.—	0.22÷130 =0.0017	
CaO—	16.72÷56.07=0.2982	÷2=0.1531
MgO—	0.19÷40.3 =0.0047	
Na_2O—	0.27÷62 =0.0043	
CO_2—	6.58÷44 =0.1495	÷1=0.1495
H_2O—	2.54÷18 =0.1411	÷1=0.1441

Thus the simplest formula for the North Burgess mineral is $2CaO \cdot (Ce,Yt)_2O_3 \cdot CO_2 \cdot 4SiO_2 \cdot H_2O$. It may be noted that the Nordmark mineral also has only one molecule of water.

The corresponding molecular ratios calculated for the Hitterö and Nordmark minerals are as follows, using 260 as the molecular weight of the yttrium-erbium group:

	HITTERÖ		NORDMARK			
	A	B	N	A	B	N
SiO_2	0.5665	0.5858	0.5274	÷4=0.1416	0.1464	0.1318
Yt_2O_3	0.1462	0.1432	0.1381	÷1=0.1462	0.1432	0.1562
Fe_2O_3			0.0181			
FeO	0.0040	0.0030		÷2=0.1491	0.1463	0.1435
CaO	0.2871	0.2818	0.2943			
MgO	0.0010	0.0008	0.0347			
Na_2O	0.0061	0.0070	0.0580			
CO_2	0.1260	0.1420	0.1160	÷1=0.1260	0.1420	0.1160
H_2O	0.3111	0.2733	0.1611	÷2=0.1555	0.1366	0.0806

It is unfortunate that the North Burgess material was not available in sufficient quantity to permit further chemical study of larger quantities.

Reactions indicating the possible presence of scandium to the extent of perhaps between 0.5 to 1 per cent were obtained, but up to the time of writing this point was still under investigation.

The analyses agree well enough to indicate the extremely close relationship of the three minerals. The Burgess mineral has a higher specific gravity than the others, somewhat different indices, and only one molecule of water, but perhaps these differences can be accounted for by the possibility that the earlier minerals were more or less altered and hydrated. For the present, therefore, it appears advisable to consider the North Burgess mineral as cenosite.

SEAMANITE, A NEW MANGANESE PHOSPHO-BORATE FROM IRON COUNTY, MICHIGAN

E. H. Kraus, W. A. Seaman, and C. B. Slawson.

During the summer of 1917 while the senior author was visiting the copper district of Northern Michigan, Professor Arthur E. Seaman of the Michigan College of Mining and Technology called his attenton to what was thought to be a new mineral, which he had recently discovered at the Chicagon mine. Professor Seaman's statement was based upon a qualitative determination of the chemical composition made by Mr. F. B. Wilson, then a member of the chemical department of the College. Several well crystallized specimens were entrusted to the senior author who determined the crystallographic and optical data. On account of the World War further investigation of the mineral was discontinued until a year ago, when the data on the crystallography and on the physical and optical properties were checked and extended in the Mineralogical Laboratory of the University of Michigan by Dr. C. B. Slawson. Professor Seaman also very kindly placed further specimens at the disposal of Dr. Slawson who used them for the chemical analyses given in this paper.

The chemical analyses by Dr. Slawson show conclusively that the mineral is a new hydrated manganese phospho-borate. Accordingly, in recognition of Professor Seaman's long and influential service as Professor of Geology and Mineralogy at the Michigan College of Mining and Technology, and his valuable contributions to the geology and mineralogy of the Upper Peninsula of Michigan, the authors propose the name of seamanite for this new mineral.

Seamanite has been found only in the Chicagon mine, five miles east and one mile north of Iron River, Michigan, in the NE 1/4 of Sec. 26, T43N, R34W, Iron County. It occurs as small acicular crystals in the crevices of a badly fractured and highly ferruginous siliceous rock. In many of the specimens of seamanite minute cube-like crystals of calcite were found which consisted of a positive rhombohedron whose edges were truncated by a small negative rhombohedron. Some of the oxides of manganese are present, usually as a thin coating.

Associated with seamanite there is also a fibrous asbestos-like mineral the identity of which has not been fully determined. From an optical study it is thought that this fibrous mineral also represents a new species. More material is, however, necessary for a chemical study. A report will be made upon this second mineral as soon as the chemical composition can be accurately determined.

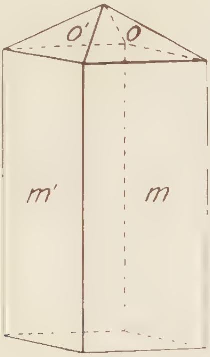

FIG. 1.

The crystals of seamanite are exceptionally slender and small. They are clear and transparent, pale yellow in color when small, but of a distinct wine yellow when larger. The largest crystals measured 10×2×1 millimeters. The observed combination consists of the unit prism, *m*, and the unit bipyramid, *o*. The crystals are commonly terminated at one end by the bipyramidal planes, *o*, while at the other end, due to a distinct basal cleavage, they frequently appear to be terminated by a face of that form (Fig. 1). The faces of the prism are generally rough and rounded and do not give very reliable readings. They are also striated vertically. W. A. Seaman reports having observed the prism (120). Since indistinct images are obtained in positions which would approximate the proper location of faces of this form, the striations may be due to an alternation between the unit and modified prisms. The faces of the bipyramid are very small, but in some instances yielded good images. Although the crystals are not terminated at both ends by bipyramidal faces they are assumed to belong to the bipyramidal class of the orthorhombic system.

The crystallographic data may be summarized as follows:

System = Orthorhombic.
Class = Bipyramidal.
$a:b:c = 0.5195:1:0.4508$.

	OBSERVED	CALCULATED
$m(110):m(1\bar{1}0)=$	*54°35′	......
$o(111):o(1\bar{1}1)=$	*37 30	......
$m(110):o(111)=$	45 52	45°29′

Seamanite has a hardness of 4 and a specific gravity of 3.128. The crystals are soluble in cold dilute acids. Before the blowpipe seamanite fuses readily, after losing its water of crystallization, to a dark slag. Seamanite is optically positive with the following indices of refraction: $\alpha=1.640$, $\beta=1.663$, and $\gamma=1.665$, (all ± 0.003). $X=a$, $Y=b$, $Z=c$, $2V$ approximates 40°, and $r<v$.

TABLE I.

	1	2	3	4
MnO	56.28	55.65	56.22	58.73
MgO CaO			1.61	1.04
FeO			.13	.10
B_2O_3			9.95	9.92
P_2O_5	16.29	15.84	16.65	14.95
H_2O	14.65	14.31	14.57	14.76
			99.13	99.50

TABLE II.

	Average	Factor			
MnO	56.42	.8000			
MgO CaO	1.33	.0277	.8292	3.259	3×1.086
FeO	.11	.0015			
B_2O_3	9.94	.1420			
P_2O_5	15.94	.1122	.2544	1.000	1×1.000
H_2O	14.57	.8090	.8090	3.180	3×1.060

Analyses 1 and 2, Table 1, are the preliminary analyses made with samples of approximately one quarter of a gram each. Carefully hand-picked samples, weighing 0.5933 grams and 0.5365 grams respectively, were used for analyses 3 and 4. The material for analysis 3 consisted of a large number of small crystals while that for analysis 4 was made up of crystals of over one-half centimeter in length. In many instances the larger crystals were coated with a fine powder which was assumed to be manganese oxide. An attempt was made to remove all of this coating but the high percentage of MnO and the low content of P_2O_5 in analysis 4 seem to indicate that some of the coating had been left on the crystals.

Water was determined in an atmosphere of carbon dioxide to prevent the oxidation of the manganese. The sample was then dissolved in hydrochloric acid and boiled with barium hydroxide to precipitate everything with the exception of the B_2O_3 which remained in solution as barium borate. B_2O_3 was determined by titrating the filtrate in the presence of mannitol. The precipitate obtained with barium hydroxide was dissolved in acid and the excess barium removed as the sulphate. From this filtrate manganese was precipitated as MnO_2 by boiling with concentrated nitric acid and sodium chlorate and determined as the pyrophosphate. The filtrate from the manganese separation was then made alkaline which precipitated the magnesium, calcium, and iron as phosphates. Ferrous oxide was determined by titration and the combined content of magnesium and calcium oxides calculated by difference. P_2O_5 was determined as magnesium pyrophosphate to which the phosphate content of the magnesium, calcium, and iron precipitation referred to above was added.*

Since B_2O_3 and P_2O_5 are not present in equal molecular proportions, the factor for the former being the larger, Table 2, it appears that the formula of seamanite should be written as $3MnO.(B_2O_5, P_2O_5) \cdot 3H_2O$. As already indicated, seamanite was partially investigated chemically by Wilson in 1917. He, too, reported that B_2O_3 predominates over P_2O_5. Wilson's results are, however, not available.

Likewise, the ratios derived from the available chemical data of lüneburgite,[1] a hydrated boro-phosphate of magnesium, do not permit of the assumption that B_2O_3 and P_2O_5 are present in the mineral in definite proportions.

LÜNEBURGITE

	Analysis	Factor	
MgO	25.3	.6275	3.000
P_2O_5	29.8	.2098	1.003
B_2O_3	12.7	.1824	.872
H_2O	32.2	1.7889	8.553
	100.0		

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* Calculated as calcium phosphate.

[1] Nöllner, *Ber. Al. München*, 291, 1870.

Furthermore, it should be pointed out that chemically seamanite is closely related to reddingite, $3MnO \cdot P_2O_5 \cdot 3H_2O$. Crystallographically the two minerals are very similar. Both are orthorhombic, and by interchanging the axes of reddingite[2] and taking one-half of the new *a* and *c* axes as the unit lengths, the axial ratios of both minerals are strikingly alike. Moreover, this similarity of values extends to the physical and optical data as the following tabulation shows.

	Reddingite	Seamanite
Composition	$3MnO \cdot P_2O_5 \cdot 3H_2O$	$3MnO \cdot (B_2O_3 \cdot P_2O_5) \cdot 3H_2O$
System	Orthorhombic	Orthorhombic
Axial ratio	0.5271:1:0.4574	0.5195:1:0.4508
Indices of refraction	$\alpha = 1.651$	1.640
	$\beta = 1.656$	1.663
	$\gamma = 1.683$	1.665
Hardness	3–3.5	4
Specific Gravity	3.102	3.128

The analyses given above and the relationship to lüneburgite and reddingite would seem to warrant the assumption that seamanite is a hydrated manganese borate, in which some of the B_2O_3 has been replaced by P_2O_5. The evidence of the chemical analyses seems to support this interpretation.

On the other hand, however, another possible interpretation of the chemical composition of seamanite should be referred to, for it is a well known fact that the accurate separation of and consequently the determination of B_2O_3 and P_2O_5 upon one small sample are extremely difficult. It is, hence, quite probable that some error has been made in these determinations. Accordingly, a somewhat lower value for B_2O_3 and a correspondingly higher value for P_2O_5 would permit of the assumption that the two acid radicals are present in equal molecular proportions. This interpretation seems to find support in the fact that in the recently described cahnite,[3] which is a hydrated boro-arsenate of calcium, the acid radicals are present in equal proportions. The mineral has the composition $4CaO \cdot B_2O_3 \cdot As_2O_5 \cdot 4H_2O$ and may be considered as a double salt of $2CaO \cdot B_2O_3 \cdot 2H_2O$ and $2CaO \cdot As_2O_5 \cdot 2H_2O$, in the ratio of 1:1.

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[2] G. J. Brush and E. S. Dana, On a new and remarkable mineral locality in Fairfield Co., Conn.; with a description of several new species occurring there: *Am. J. Sc.*, 1878, **16,** 120; Larsen, The Microscopic Determination of the Non-Opague Minerals, *U. S. Geol. Surv., Bull.* **679,** p. 126.

[3] C. Palache and L. H. Bauer, Cahnite, A New Boro-arsenate of Calcium from Franklin, New Jersey: *Am. Mineral.*, 1927, **12,** 149–153.

Consequently, according to this second interpretation of the chemical composition of seamanite the mineral may be regarded as a double salt of $3MnO \cdot B_2O_3 \cdot 3H_2O$ and $3MnO \cdot P_2O_5 \cdot 3H_2O$, in equal proportions. Considering the possibility of a plausible explanation of the composition from the structural standpoint the interpretation as a double salt has much in its favor.

To determine which of these two views is correct it is obvious that further chemical study is necessary. It has, however, been definitely established that seamanite is a new hydrated phosphoborate of manganese.

TRANSLATION-GLIDING IN CRYSTALS OF THE NaCl STRUCTURAL TYPE (CONCLUDED)

M. J. Buerger, *Massachussetts Institute of Technology.*

(*Continued from page* 187)

CORRELATION OF TRANSLATION-GLIDING AND STRUCTURE

The Translation-gliding Direction

It is well known that crystals of the NaCl type reflect infra-red radiation of certain frequencies exactly as metals reflect ordinary light; these reflected rays are known as residual rays. In order to account for the residual rays according to the electromagnetic theory it is necessary to assume that crystals contain charged particles, which calculations show must be of the order of magnitude of atoms. From this it has been supposed that crystals are built up of charged atoms, or ions, and that the cohesive crystal forces are the attractive forces between the unlike charges of the ions. It is known that the mutual gravitational attraction of particles is not sufficient to account for the experimental strength of crystals, but calculations based on ion attraction give values of about the right order of magnitude.

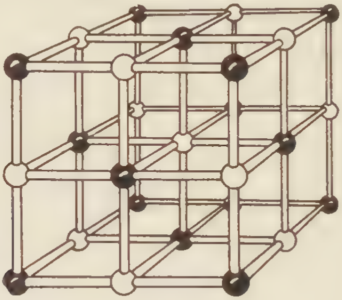

Fig. 7.

A unit cell of the NaCl structural type is shown in figure 7. The translation direction $[1\bar{1}0]$ may be seen to be a unique kind of direction in the structure; it is the direction of densest rows of like ions. Since like ions bear like charges, and unlike ions bear opposite charges, the general significance of the translation direction becomes apparent. For since every ion is exactly like any other of like charge, it is obvious that if any plane of ions containing this row is displaced in the direction of the row by the distance (which may be termed the unit translation-gliding distance) which separates like ions, the original and final configurations of ions, and hence charges, will be identical, and all the properties of the crystal before and after gliding will (ideally) be the same.

While $[1\bar{1}0]$ obviously offers at once the simplest and shortest path for t, there are an infinite number of more complicated directions which would give the same result, as far as initial and final states are concerned. For the translation plane (110), the simplest of these other possible translation directions, namely, [010], may be ruled out as electrostatically impossible, for at the mid-translation position, the original configuration of charges across the translation plane would be just reversed, plus for minus and minus for plus. Hence if the normal configuration results in a net attraction across the translation plane, this mid-translation configuration results in a net repulsion of approximately an equal amount. An attempt to produce translation in the direction [010], therefore would be attended by the strongest repulsion, which would prohibit its production. The same kind of reasoning, less rigorously, may be applied to any possible direction in the plane (110), by regarding these planes as composed of alternate rows of plus and minus charges extending in the direction $[1\bar{1}0]$. Normally, a plus row is immediately above a minus row. Translation in the direction $[1\bar{1}0]$ maintains this disposition of rows, as such, unaltered, but translation in any other direction requires a row to occupy a position directly above another of like charge at the mid-translation position, a situation reversing the normal arrangement. Furthermore, any difference in radii of the two kinds of ions composing the structure makes the path $[1\bar{1}0]$ a series of grooves in (110) along which the slipping movement might be expected to be guided.

For the translation plane (001), the following analysis of translation directions will be found useful: For $T=(001)$, all directions have the form $[hk\mathrm{O}]$ or the equivalent $[h\bar{k}\mathrm{O}]$. When $h+k$ is odd, translation in any of these directions would bring about the following condition: Considering one part of the crystal as fixed, the other as undergoing actual gliding, at half the unit translation distance, every ion in the displaced part occupies a position normally occupied by one of opposite charge. Hence if the normal configuration results in net attraction of the two parts of the crystal across the glide plane (001), the new configuration requires repulsion across that plane by an approximately equal amount. Maximum repulsion, thus, opposes translation by these paths. For a direction in which $h+k$ is even, the same conditions are approached, at some time during translation, and the more closely the more complicated the indices. This leaves the simplest direction of the type when $h+k$ is even, namely $[1\bar{1}0]$, as least opposed to gliding, and hence this becomes the translation direction. Furthermore, any difference in ionic radii of the constituent ions will make $[1\bar{1}0]$ the path requiring least transverse displacement of planes during gliding.

There is a peculiarity about the gliding elements $T=(001)$, $t=[h\bar{k}\mathrm{O}]$, where $h+k$ is even, which will subsequently be shown to have a bearing on which plane functions as a glide plane. A glide of half the unit translation-gliding distance in any of these directions (in actual performance, $[1\bar{1}0]$ alone need be considered) brings about an arrangement of charges such that every charge on one side of the glide plane is equally distant and symmetrically placed with respect to an equal number of like and unlike charges across the glide plane, and there is thus on cohesion across the glide plane in the mid-translation position.

The Translation-gliding Plane

Galena and altaite glide only along cube planes while the other crystals glide along both cube and dodecahedron planes, or with very marked preference to gliding along dodecahedron planes alone. For a series of crystals of identical structural arrangement, this behavior seems, at first sight, truly remarkable.

It might be supposed that crystals composed of divalent ions might glide differently than those composed of monovalent ions, and that this might possibly account for the unique behavior of galena and altaite. But the ion charge is, of itself, ruled out of consideration since the divalent-ion periclase glides in quite the same manner as do the monovalent ion alkali halids, and not as galena and altaite.

The size of the unit cell can, of itself, have no effect upon the glide-plane since a change in scale necessarily changes all distances, and hence coulomb forces, proportionally. This is easily confirmed by preparing a correlation table between unit cell size and glide planes. The table indicates lack of correlation.

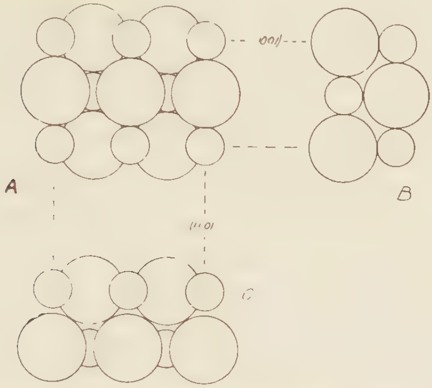

FIG. 8. NaCl structural type, as seen looking along translation-gliding direction [1$\bar{1}$0].

A. Normal ionic configuration.

B. Configuration at half unit translation-gliding distance, with $T=(110)$.

C. Configuration at half unit translation-gliding distance, with $T=(001)$.

Variation in ease of gliding along different planes might supposedly be ascribed to varying smoothness of these planes and thus be related to the ratio of the radii of constituent ions. This can best be illustrated by viewing the structure along the translation direction [1$\bar{1}$0] (figure 8*A*). Then all possible planes, T, appear as traces. In the figure, the ion radii are to scale for MgO. Considering, for the first approximation, that the ion radii remain sensibly constant during gliding, it can be seen from figures 8*B* and 8*C* that gliding along either (110) or (001), respectively, involves lifting the plane as well as pushing it. The amount of lift, and thus a measure of the "roughness" of the planes can be calculated.

The amount of lift in gliding along (001) is a function of the ion radius ratio up to a certain ratio beyond which there is no lift. Figure 9 shows that in order that the lift be zero, there must

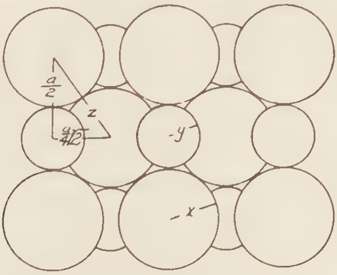

FIG. 9.

be no overlap of the larger ions in their normal positions as seen along $[1\bar{1}0]$. That is,

$$z \geqq 2x, \text{ where } x \text{ is the radius of the larger ion.} \tag{1}$$

From the geometry of the NaCl arrangement (fig. 9),

$$z = \sqrt{\left(\frac{a_0\sqrt{2}}{4}\right)^2 + \left(\frac{a_0}{2}\right)^2} \quad \text{where } a_0 \text{ is the length of a side of the unit cell,} \tag{2}$$

or, simplifying,

$$z = a_0\sqrt{\frac{3}{8}}. \tag{3}$$

Substituting the value of z given by (1),

$$2x \leqq a_0\sqrt{\frac{3}{8}}, \tag{4}$$

or,

$$x \leqq \frac{a_0}{2}\sqrt{\frac{3}{8}}. \tag{5}$$

Now, the radii of the ions are not independent of each other but, if the radius of the larger is designated by x, and the smaller by y,

$$x + y = \frac{a_0}{2} \tag{6}$$

or,

$$y = \frac{a_0}{2} - x. \tag{7}$$

Substituting the value of x given by (5),

$$y \geqq \frac{a_0}{2} - \frac{a_0}{2}\sqrt{\frac{3}{8}}. \tag{8}$$

Dividing (8) by (5)

$$\frac{y}{x} \geqq \frac{\frac{a_0}{2} - \frac{a_0}{2}\sqrt{\frac{3}{8}}}{\frac{a_0}{2}\sqrt{\frac{3}{8}}} \tag{9}$$

or, numerically,

$$\frac{y}{x} \geqq 0.63.$$

That is, above an ion radius ratio of 0.63 the (001) planes require no lift for translation in the direction $t = [1\bar{1}0]$. Below this ratio, an increasing lift is required along cube planes, down to a value of $x=\frac{a_0\sqrt{2}}{4}$, which corresponds to cubic close packing[22] for the larger ions (figure 10). The maximum separation of (001) planes during gliding is then $\frac{a_0}{4}\sqrt{6}$. The normal separation is $a_0/2$. Thus the lift is

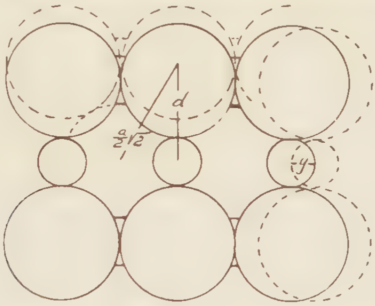

FIG. 10.

$$\text{maximum lift } (001)=\frac{a_0\sqrt{6}}{4}-\frac{a_0}{2}=0.112a_0.$$

For gliding on (110) the maximum separation may be seen from figure 8*B* to be equal to the sum of the radii of the larger and smaller ions, which is therefore constant, and equal to $a_0/2$. Figure 10 shows the constant lift to be equal to the radius y.

$$\text{Lift } (110)=y \tag{10}$$

$$=\frac{a_0}{2}-x \quad \text{from (7)} \tag{11}$$

$$=\frac{a_0}{2}-\frac{a_0\sqrt{2}}{4} \tag{12}$$

$$=0.147a_0.$$

That is to say, the lift required for translation along (110) is always constant and equal to $0.147a_0$; the lift required along (001) varies with the ion radius ratio. For all ratios, however, the lift in gliding along (001) is less than for (110), and is zero for values of the radius ratio greater than 0.63.

---

[22] Below this ratio, the NaCl type of structure is impossible.

Since lift is more or less analogous to friction, it might be supposed that all crystals having an ion radius ratio above 0.63 would glide on cube planes, while those having low ratios might glide on both cube and dodecahedron planes. For this purpose the following correlation table was prepared, using Goldschmidt's[23] values of ion radii:

Crystal	Radius of Cation	Radius of Anion	$\left(\frac{\text{Radius of Cation}}{\text{Radius of Anion}}\right)$	Translation planes	
RbCl	1.49	1.81	.823	(110)	?
PbS	1.32	1.74	.759	—	(001)
NaF	0.98	1.33	.737	(110)	(001)
KCl	1.33	1.81	.735	(110)	(001)
KBr	1.33	1.96	.678	(110)	(001)
PbTe	1.32	2.03	.650	—	(001)
NH_4I	1.43	2.20	.650	(110)	?
Theoretical smooth plane ratio 0.63					
KI	1.33	2.20	.604	(110)	(001)
MgO	0.78	1.32	.591	(110)	?
NaCl	0.98	1.81	.541	(110)	(001)
NaBr	0.98	1.96	.500	(110)	(001)
NaI	0.98	2.20	.445	(110)	(001)

The table brings out the fact that while crystals known to glide only on (001) fall above the smooth-plane ion ratio 0.63, obviously this supposedly critical ratio does not separate crystals which glide on (110) and (001) from those which glide only on (001) and hence has, *of itself*, no particular significance, and ease of gliding on (001) as against ease of gliding on (110) shows no correlation with ion radius ratio.

In an attempt to obtain a hint at what lays at the bottom of this difference in gliding behavior of different crystals built on the same plan and differing only in the kinds of ions in their constitution, the obvious course is to correlate all sorts of ion properties against gliding behavior. Correlation tables, therefore, were prepared, and it was found that the only fundamental ion property which showed any regular and gradational correlation was that of polarizability. Following are the polarizabilities of the ions concerned.[24]

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[23] V. M. Goldschmidt, Geochemische Verteilungsgesetze der Elemente VII, Die Gesetze der Krystallochemie. *Skrifter utgitt av Det Norske Videnskaps-Akademi i. Oslo, I. Mat.-Nat. Klasse*, **1926,** *No.* 2.

CATIONS		ANIONS	
Pb^{++}	3.1×10^{-24} cm.^{3}	Te^{--}	9.6×10^{-24} cm.^{3}
Rb^{+}	1.81 "	S^{--}	7.25 "
K^{+}	0.85 "	I^{-}	6.28 "
Na^{+}	0.21 "	Br^{-}	4.17 "
Mg^{++}	0.12 "	O^{--}	3.1 "
		Cl^{-}	3.05 "
		F^{-}	0.99 "

It is immediately apparent from the table that crystals which glide only on (001), *i.e.*, altaite and galena, are composed of anions which head the list and of cations which head the list. Crystals which glide practically only along (110), *i.e.*, periclase, NaF and NaCl, are composed of ions which foot the lists. Crystals which glide along both (001) and (110) with nearly equal ease, *i.e.*, the sodium and potassium bromides and iodides, are composed of ions of intermediate positions in the lists. The correlation is brought out somewhat more forceably by the following table, in which the sums of the polarizabilities of the cations and the polarizabilities of the anions are compared with the planes of gliding. The table prepared in this fashion tends to show that *both* ions have a share in conditioning the gliding plane and the gliding ease.

CRYSTAL	SUM OF POLARIZABILITY OF BOTH IONS	GLIDE PLANES		
PbTe	12.7×10^{-24} cm.^{3}	(001)	↑ Increasing ease of gliding on (001) and increasing general plasticity	Increasing *relative* ease of gliding on (110) and decreasing general plasticity. ↓
PbS	10.3 "	(001)		
KI	7.13 "	(001) and (110)		
NaI	6.49 "	(001) and (110)		
KBr	5.02 "	(001) and (110)		
RbCl	4.86 "	?[a] and (110)		
NaBr	4.38 "	(001) and (110)		
KCl	3.90 "	(001) and (110)		
NaCl	3.26 "	practically only (110)		
MgO	3.2 "	practically only (110)		
NaF	1.20 "	practically only (110)		

[a] Data for gliding on (100) is not available for RbCl.

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[24] From *Handbuch der Physik*, Volume **24**, *Berlin*, 1927, p. 449.

The value for doubly negative lead was not available but the approximate value was kindly supplied by Dr. B. E. Warren, of the Department of Physics, Massachusetts Institute of Technology, who had occasion to calculate it for other purposes

The correlation shown in the table is conspicuously in harmony with the experimental results. Thus, haloid for haloid, the potassium salt precedes the sodium salt, and for either series, the sequence runs: iodide, bromide, chloride, fluoride, in harmony with the experimental data collected.

Once the correlation between gliding and polarizability is established, it is not difficult to find the explanation. An electric field has a tendency to separate the positive nucleus from the negative electron shell of an ion. Polorizability is the electric moment thus set up in the ion due to a unit homogeneous electrostatic field. Since this property will not be dealt with mathematically,[25] it will be sufficient to explain its influence on the present problem as follows: If two like ions are separated from one another, they will repel each other less if their polarizabilities are high, and more so if their polarizabilities are low. The property of polarizability increases the attraction and decreases repulsion between ions as usually calculated.

Now it has already been demonstrated that the cube plane is smoother under all conditions than the dodecahedron plane, and that it is very smooth indeed above an ion radius ratio of 0.63. It has already been noted, also, that in gliding along cube planes, a position is approached, halfway along the unit gliding distance, where every ion is just as near a like ion on the other side of the translation plane, as it is to a corresponding unlike ion. Assuming unpolarizable ions, there is no attraction across the plane in this condition, and one part of the crystal could be lifted away from the other without expenditure of any energy. Thus, the maximum amount of work would be done by gliding along this plane, and, since the unit gliding distance is the same regardless of the gliding plane, the average maximum repulsion must be overcome.

When polarizability is taken into account, it is obvious that at the mid-gliding position on (001), the attraction of unlike ions is increased and the repulsion of like ions diminished, depending in amount on the polarizabilities of both ions involved. Thus in gliding to the mid-point of the unit gliding position on (001) the planes retain cohesion and the maximum work or maximum average force is no longer required, and the plane of gliding then becomes dependent on polarizability and smoothness. Since the glide plane depends on the attitude of the load, the cube plane of an NaCl-like crystal composed of strongly polarizable ions becomes at least a possible glide plane. When, as is doubtless the case with altaite and galena, the strong polarizabilities of the ions offer a path of relatively little resistance along (001), gliding takes place along this very smooth plane. If the polarizabilities of the ions are very low, as in NaF, especially directed pressure is necessary to show any trace of gliding along (001), and the crystal glides, by preference, along (110) under a random load, and even then with difficulty due to the roughness of this plane. Not only the preferred plane of gliding, but also the ease of gliding is thus dependent upon the polarizabilities of the ions.

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[25] However see writer's note at end.

The Taricco Figure on Galena

The unusual set of gliding elements displayed by galena in the production of Taricco's figure occur under circumstances which are likewise unusual. As a rule, a glide plane extends completely across a crystal. Under such conditions a forced glide in the NaCl structure along (100) in the direction $[00\bar{1}]$, could it be accomplished, would, at half the unit gliding distance, replace plus by minus charges, and *vice versa*, on one side of the glide plane, and a repulsion approximately equal[26] to the normal attraction across (100) planes would result along the active glide plane; consequently cleavage would ensue.

Under the conditions of the Taricco figure, instead of a single plane gliding alone, a prism surrounded by four planes glides. Thus the repulsion across the (100) glide plane is equal and opposite to that across the $(\bar{1}00)$ glide plane, and since the structure of the shell surrounding the prism completely encloses it, cleavage can not ensue. The cross section area of the shell, of course, is enormous compared with that of the gliding surface of the prism, so the surrounding shell can not fail by cleavage.

Still, this figure is unknown for the NaCl-like alkali halides. If an attempt is made to produce a Taricco figure on any of them, a quite different figure results which has been subject to considerable exposition by Mügge.[27] Radiating from the needle, four parting clefts, (110) and $(1\bar{1}0)$ appear. Between each pair of cracks, a portion of the crystal is displaced away from the needle and upward;

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[26] Assuming rigid spherical ions lacking polarizability.

[27] O. Mügge, Ueber Translationen und verwandte Erscheinungen in Krystallen: *Neues Jahrb.*, **1898,** I, pp. 138–145.

translation-gliding has taken place along $(10\bar{1})$, (011), $(\bar{1}1\bar{1})$, $(0\bar{1}\bar{1})$ in the usual translation direction.

The explanation of the difference is again probably to be found in polarizability. It would appear that the component ions of galena are so polarizable that the repulsion normally to be expected with translation in the direction $[00\bar{1}]$ on (100) is so largely mitigated that this mode of gliding is even easier than in the direction $[101]$ on $(10\bar{1})$.

CONCLUSIONS

Conclusions Regarding NaCl-like Crystals

The findings may be briefly summarized as follows: For crystals of the NaCl-like structure, the translation direction, *t*, is determined by the densest rows of like-charged ions. The translation plane, *T*, is a function both of ion radius ratio and of the polarizabilities of the constituent ions. Translation along (001) is associated with high polarizabilities, translation along (110) with low polarizabilities; with intermediate values both (001) and (110) may function as translation-gliding planes under favorable conditions of load.

It is interesting to observe that the translation-gliding direction is identical with the unit translation as used in the geometrical crystal structure theory, provided the original lattice coordinates are retained. The coordinates in practical use have been chosen in such a way as to display the cubic symmetries. Retaining original coordinates, the translation direction, unit translation, direction of closest equivalent lattice points, and thus direction of closest like charges, are identical.

Extension of Correlation to Other Crystals

At the time of carrying on the research above detailed, the following crystals were known to the writer for which there were available both sufficiently critical translation-gliding and structural data to permit of correlations: salamomniac and low-NH_4Br; fluorite; magnesite, siderite, rhodochrosite and smithsonite; dolomite; barite; and anhydrite. For all of these, correlations proved a relation of gliding to structure similar to that found in the NaCl-like crystals, with minor modifications. Thus the translation direction is that of alignment of nearest like charges, but the points occupied by the like charges need not necessarily be equivalent, nor need the line of charges be necessarily truly straight, but may be very slightly zig-zig, etc.

Also, when the original research was carried out, the following crystals were known to the writer for which the structural and gliding data, while not complete, were of such a character as to permit of partial[28] correlation: chalcopyrite, ice, brucite, molybdenite, and graphite. Each of these crystals fitted into the scheme already proposed.

Conclusion of a General Nature

In the foregoing discussions of twenty-seven different crystal species, the fact stands out clearly that the translation direction is specific for a given structural arrangement. However crystals of the same structural arrangement may otherwise differ from one another in properties, they all have the same translation direction in common. In analyzing the various structures for the cause of this uniqueness, it has been pointed out that in each case the translation direction has the structural character of alignment of closest like leptons for all leptons (considered at the same time) in the structure. An adequate mechanistic explanation of the gliding direction has been presented on the assumption that the leptons are individually charged, and thus have the characters of ions, an assumption which easily follows from electrochemical considerations and which has been used to advantage in explaining residual rays and the cohesive forces in crystals.

Two portions of a crystal may relinquish their mutual, normal configuration upon application of sufficient stress, and regain a new, but equivalent, normal configuration provided the alteration pursues a path which allows them to retain cohesion. If cohesion is electrostatically conditioned, so also is translation-gliding, which implies continued cohesion. Of the numerous paths which translation might conceivably take to restore the original configuration of the crystal, one offers a minimum resistance, or, what amounts to the same thing, a minimum loss of cohesion, and this becomes the actual translation direction. For all available data, this unique path has been shown to be connected with paths of closest like-ions, assuming the leptons to be ions, and other paths have been shown to be impossible. This may be regarded as a substantiation of, and independent evidence for, the theory of the existence of ions in crystals, though not necessarily a proof of it. The successful correlations also have the nature of a partial check on the correctness of the crystal structures considered.

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[28] Thus, in crystals, for which T is known, but t unknown except that it exists as three equivalent directions in T, the correlation was regarded as established if the three theoretical directions, t, determined a theoretical T which was identical with the actual T.

WRITER'S NOTE: This paper was presented in May, 1929, before an informal gathering of Harvard and Massachusetts Institute of Technology physicists and mineralogists interested in crystal structure. At that time, Dr. Hans Müller, Assistant Professor of Physics at the Massachusetts Institute of Technology, evinced a considerable interest in the relation between gliding and polarizability. He informed the writer that this relation would be amenable to a mathematical demonstration. Since then, Dr. Müller has investigated the subject from this viewpoint, and the results of his study, bearing out the writer's correlations in very exact form, will appear in an early number of this Journal.

NOTES AND NEWS

EUHEDRAL MAGNESITE CRYSTALS FROM WINKLER COUNTY, TEXAS

JOHN T. LONSDALE, *A. & M. College of Texas.*

The magnesite crystals described in this paper were obtained from drill cores from wells of the Southern Crude Oil Purchasing Company. Most of the material studied came from the company's Well 89-E-1, located 2310 feet from the east line and 330 feet from the north line of Section 40, Block B-5, Winkler County, Texas. Additional specimens came from a nearby well the exact location of which is not known. The core from Well 89-E-1 was taken at 2690 feet, the formation being Permian and known as the "white lime". The core from the nearby well is believed to have been taken at a level several hundred feet higher, from the "brown lime", a higher Permian formation. The specimens were submitted to the writer by A. L. Ackers and E. M. Hawtof of the geological staff of the company.

Euhedral magnesite crystals are not common. Austin F. Rogers has described crystals from San Jose, California, and Lillian M. Dobbel crystals from Orangedale, Nova Scotia.[1] There are only a few additional occurrences of crystals from the whole world and textbooks of mineralogy contain very few data on the crystallography of the mineral. The rarity of the crystals and the fact that those from Winkler County are different crystallographically from the other North American occurrences accounts for the present note.

The magnesite crystals occur disseminated through fragments of the well cores mentioned above. They appear much as phenocrysts in an aphanitic igneous rock. The matrix is a dolomitic limestone containing chert or flint nodules. Many of the magnesite crystals are stained with petroleum or asphalt. The crystals have originated by replacement of the dolomite by magnesium bearing solutions.

The crystals measure from about 1 mm. up to about 5 mm. in length. They were separated from the matrix by digestion in dilute hydrochloric acid with the result that the crystal faces were dimmed and in some instances destroyed. Relatively few crystals with good terminations were obtained because of this fact. The dominant forms and the only ones definitely recognized on the crystals are a prism terminated by a rhombohedron. Some crystals apparently tapering at both ends suggested a steep scalenohedron and others a pinacoid but neither of these forms are certain. The crystals examined by Rogers have a scalenohedron, prism and pinacoid as the dominant forms and those described by Miss Dobbel show a prism and pinacoid as dominant forms with minor development of rhombohedron and scalenohedron. The Winkler County crystals are therefore distinctly different in habit since they commonly show a prism terminated by a rhombohedron. The angle of the rhombohedron was measured on the stage of a petrographic microscope from fragments of the mineral and from thin sections. The average of several measurements gave 72° 48′ which is close to the value usually given for magnesite.

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[1] Rogers, Austin F., Euhedral Magnesite Crystals from San Jose, California: *American Mineralogist*, Vol. **8**, pp. 138–140, 1923. Dobbel, Lillian M., Magnesite Crystals from Orangedale, Nova Scotia: *American Mineralogist*, Vol. **8**, pp. 223–228, 1923.

A number of the crystals were analyzed by P. J. A. Zeller, of the Texas Engineering Experiment Station with the result given below:

MgO	47.24
CaO	1.47
FeO	1.67
CO_2	49.49
	99.87

In this analysis the crystals were dissolved in hydrochloric acid so that the result represents only soluble material. There was left a small amount of insoluble material derived from minute inclusions in the mineral. Thin sections revealed a very small amount of iron oxide some of which may have gone into solution furnishing at least part of the iron of the analysis.

The indices of refraction obtainable from a cleavage of the mineral are 1.595±.003 and 1.72±.005, the latter being ω, the former a value intermediate between ω and ϵ diagnostic for magnesite of the composition shown in the analysis.

Dr. Victor M. Goldschmidt, professor of mineralogy and crystallography at the University of Göttingen, gave a number of lectures on chemical geology at the University of London.

Dr. William F. Foshag of the Smithsonian Institution and the U. S. National Museum gave a series of lectures at Princeton University on the "Ore Deposits of Mexico". One lecture was also given on the "Saline Deposits of the Western United States".

The Smithsonian Institution has announced the gift of a perfect sphere of flawless rock crystal, believed to be the largest in the world. Mrs. Worcester Reed Warner gave the gift as a memorial to her late husband whose achievements were largely in the manufacture of astronomical instruments made from quartz. The crystal ball measures 12⅞ in. in diameter and weighs 106¾ pounds. The block of quartz from which the ball was cut is said to have come from Burma and must have weighed over 1000 pounds. It was cut in China and polished in Japan. The ball is now the property of the United States National Museum.

A second impression of the well known work "Petrographic Methods" by Arthur Holmes has recently been issued by Thomas Murby & Co., London. It was reprinted by the phototype process and because of this fact can be offered at a great reduction in price compared with the first edition. The cost of the first edition was 31/6d, while that of the second is only 15/–.

A new method of imbedding extremely fine mineral particles or ore samples in bakelite in preparation for microscopic study is described by R. E. Head and Morris Slavin in Technical Paper No. 10 of the United States Bureau of Mines. The twelve page pamphlet is entitled "A New Development in the Preparation of Briquetted Mineral Grains" and can be purchased from the Bureau for 15 cents.

Dr. E. L. Bruce, Miller Memorial Professor of Geology at Queen's University, Kingston, Canada, sailed on May 23rd to spend the summer chiefly in Finland.

PROCEEDINGS OF SOCIETIES

NEW YORK MINERALOGICAL CLUB

Minutes of the March Meeting.

A regular monthly meeting of the *New York Mineralogical Club* was called to order by President Herbert P. Whitlock at the American Museum of Natural History on the evening of March 19, 1930, with an attendance of 56.

Mr. John T. Gordon and Miss Gwynne Richards of New York City were elected to membership.

Dr. Kunz exhibited an unusually long (38 cms.) tapering crystal of colorless quartz from Brazil, and Mr. Grenzig showed a large "half-breed" of crystallized copper and silver from the Lake Superior district.

The speaker of the evening was Dr. W. F. Foshag, of the U. S. National Museum, who addressed the Club on "*Collecting Minerals in Mexico.*"

The rocks of Mexico are principally limestone of Comanchian and Cretaceous age, which are overlain in places by Tertiary lava flows, and underlain by granites. Most of the ore deposits (chiefly copper, silver, lead, and zinc ores) occur along faults in the central plateau region, and may be classified as veins, replacements in limestone, contact metamorphic deposits, and others. The replacements in limestone furnish the most constant supply of good mineral specimens.

The speaker described in detail a number of localities which he visited on a collecting trip a few years ago. Unusually fine specimens of wulfenite (with pyramidal habit), cerussite, anglesite, vanadinite, descloizite, pyrrhotite, gypsum (crystals up to six feet in length), hillebrandite, spurrite, and other minerals were obtained on this expedition. The places visited were illustrated by a large number of excellent lantern slides.

Horace R. Blank, *Secretary*

PHILADELPHIA MINERALOGICAL SOCIETY

Academy of Natural Sciences, Philadelphia, March 6th, 1930

A stated meeting of the *Philadelphia Mineralogical Society* was held on the above date, Mr. Toothaker presiding. Upon favorable recommendation of the Council, Dr. Leopold Pessel was elected a member of the Society.

Dr. George Frederick Kunz of New York City, was then introduced and gave an interesting address on "*Gems: Past, Present and Future*". Dr. Kunz first described gems used by the ancients and referred to the many legends and myths attached to gems in remote as well as in modern times. Diamonds and the diamond industry were discussed at some length and many interesting details were given on the art of cutting. He stated that stones as small as one six hundred thousandth of an ounce could be cut by present methods. The descriptions of his many experiences and anecdotes relating to his numerous trips to distant parts of the world held the interest of his audience. His early experiences in collecting specimens appealed strongly to the members of the Society. A large collection of colored slides and an exhibition of beautiful specimens from his personal collection added greatly to the pleasure of the evening. After a rising vote of thanks the meeting was adjourned with an attendance of 175.

Lester W. Strock, *Secretary*

Academy of Natural Sciences, Philadelphia, April 3rd, 1930

A stated meeting of the *Philadelphia Mineralogical Society*, was held on the above date with Mr. Toothaker in the chair. Mr. Henry Welkey was proposed for membership in the Society. Mr. Ernest G. Enck addressed the Society on "*Economic Uses of Rare Elements*".

The speaker described the sources, chief uses and future possibilities of the following elements: beryllium, titanium, zirconium, thorium, cerium, tantalum, tungsten, uranium, and molybdenum. He exhibited many specimens of the elements along with their salts and manufactured products in which the elements were used. Metalic zirconium was shown to be combustible by a demonstration with all lights turned out. The exhibition of tiles and porcelains which had been colored by the addition of titanium and cerium oxides was very striking as were also bricks and crucibles of zirconium oxide. He predicted that the rare minerals of to-day would be the common ones of the future and that the mineralogists were doing pioneer work by diligently seeking new localities for these minerals. Mr. Enck's talk was very much enjoyed by all present and an enthusiastic vote of thanks was given him by all present.

Mr. Samuel G. Gordon, of the Academy staff, was welcomed back after an extensive collecting trip in South America and Africa, he briefly outlined his travels in a few remarks but promised to give a detailed account of his experiences at the June meeting of the Society.

Messrs. Oldach and Cienkowski reported on recent trips to local quarries and several junior members showed some attractive finds of garnets and beryls in the Philadelphia district. The attendance was 48.

Lester W. Strock, *Secretary*

MINERALOGICAL SOCIETY OF GREAT BRITAIN AND IRELAND

Mineralogical Society, *March 18*.—Dr. G. T. Prior, President, in the chair.

Professor W. L. Bragg, O.B.E., M.A., F.R.S., (Professor of Physics in the University of Manchester) delivered a lecture on the "*Structure of Silicates*". Illustrating the lecture by models and diagrams he demonstrated the principal results so-far achieved by his investigations of the structure of silicate minerals by means of *x*-rays.

W. Campbell Smith, *General Secretary*

NEW MINERAL NAMES

Stibiopalladinite

R. Adam: A new platinum mineral from the Potgietersrust platinum fields. *Jour. Chem. Met. Min. Soc. South Africa*, **29**, 249–250, 1927. *cf. Am. Mineral.*, **13**, 201, 1928.

Chemical Properties: *cf. Am. Mineral., op. cit.*

Mineralographical Properties: Color white with distinct tinge of yellowish rose. Between crossed nicols it is completely dark gray when unetched, but shows a weak color change when etched. Etches with aqua regia with development of grain structure. With HCl and $KClO_3$ it etches readily, the individual grains becoming light yellowish to yellowish brown. Continued etching with this reagent gives an adherent precipitate. After etching it shows an indistinct radial structure of thick short prisms.

W. F. Foshag

Klebelsbergite

Victor Zsivny: Klebelsbergit, ein neues Mineral von Felsöbánya (Klebelsbergite a new mineral from Felsöbánya). *Mat. Természettud. Értesitö*, **46**, 19–24, 1929. German summary.

Chemical Properties: A basic sulfate of antimony with water. Fusible. Dissolves in strong hydrochloric acid.

Crystallographical Properties: Monoclinic: Forms (010), (001), (101), ($\bar{1}$01). $\beta = 88.2°$.

Physical and Optical Properties: Color sulfur yellow. Biaxial negative. $Bx_a = X = b$. $Y:c = +1.8°$. $n > 1.74$. Brittle.

Occurrence: Found as fine radiated needles on stibnite crystals at Felsöbánya, Hungary.

W. F. F.

Lessingite

V. Silberminz: Sur le gisement de cérite, de bastnaésite et d'un minéral nouveau, la lessingite, dans le district minier de Kychtym (Oural). (On the occurrence of cerite, bastnaesite and a new mineral, lessingite, in the district of Kychtym (Urals)). *Compt. Rend. Acad. Sci. URSS.*, Ser A., pp. 55–60, **1929**.

Name: In honor of F. Loewinson-Lessing, Russian petrologist.

Chemical Properties: A silicate of calcium and the rare earths. Analysis: SiO_2 19.85, Al_2O_3 0.26, Fe_2O_3 0.65, Ce_2O_3 22.48, $(Di, La)_2O_3$ 36.65, $(Yt, Er)_2O_3$ 3.42, MnO 0.88, CaO 11.71, MgO 0.17, $(K,Na)_2O$ 0.08, P_2O_5 1.13, F 0.54, CO_2 0.35, H_2O+ 1.56, H_2O- 0.38, ($O = F_2$ 0.23). Sum 99.88.

Physical and Optical Properties: Color greenish to reddish yellow, on fresh fracture, cerise red. Luster vitreous. Hd. 4.5. Cleavage none.

$\gamma = 1.785$. Birefringence = .006 (approx.). 2V = 44° (approx.). Non pleochroic.

Occurrence: Found as rolled pebbles with bastnaesite (kychtymo-parisite), cerite, torneböhmite and allanite in the stream Motchaline-log, an affluent of the Borzovka River near Kychtym, Urals.

W. F. F.